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GB 1037195
GB 835971
GB 748025
GB 669863
GB 594028
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H3T

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(54) Oscillator mode suppression apparatus having bandpass effect

(57) An apparatus utilizing the basic oscillation characteristics of the Colpitts or Pierce and Hartley oscillator configurations. In this embodiment the basic shunt reactive shunt arms (14, 16) are replaced with a selected pair of tank circuits or one of the shunt arms with a series or parallel tank circuit. These tank circuits are tuned such that the sign of their effective reactances are the same between the range of resonant frequencies of the individual tank circuits or of the series and parallel resonant frequencies of the series-parallel tank. When this occurs and their sign differs from the sign of the effective reactance of the series reactive element, there is an 180° signal phase shift in the feedback loop, and therefore oscillation. Resonator 12 is a crystal. Other examples of the shunt arms are described Figs. 3a–3e.

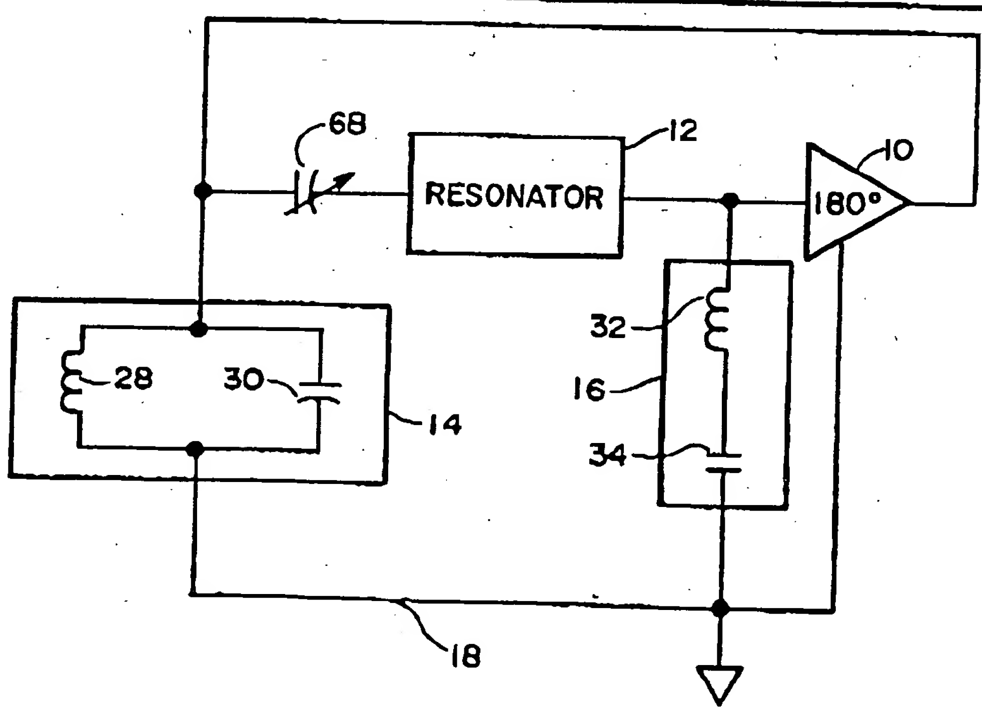

Fig. 1

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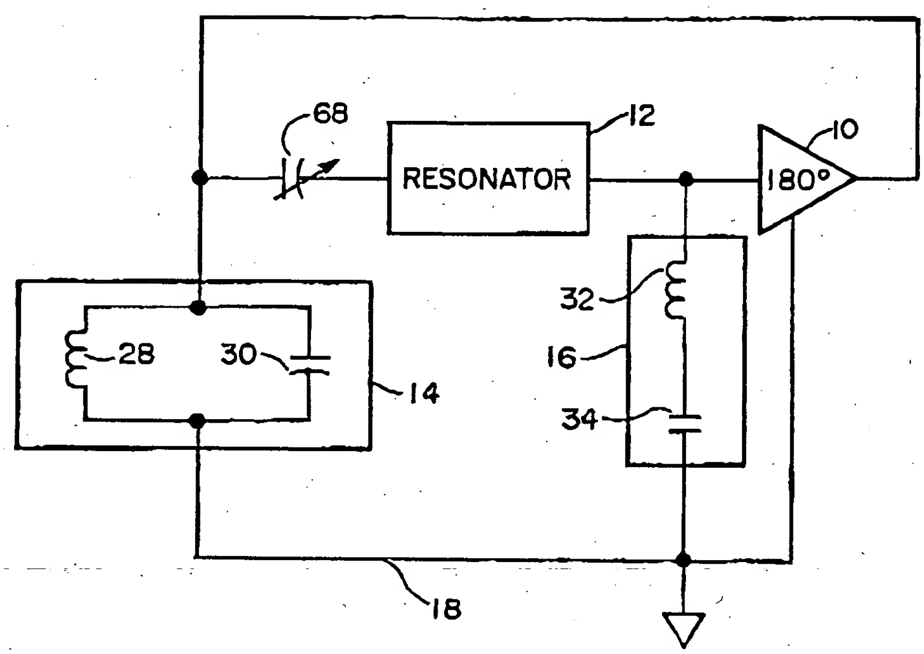

Fig. 1

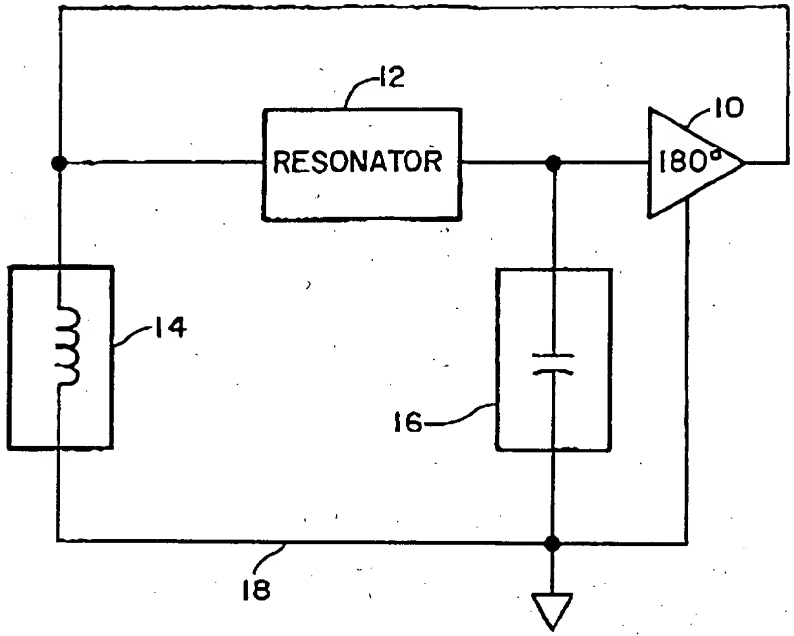

Fig. 2a

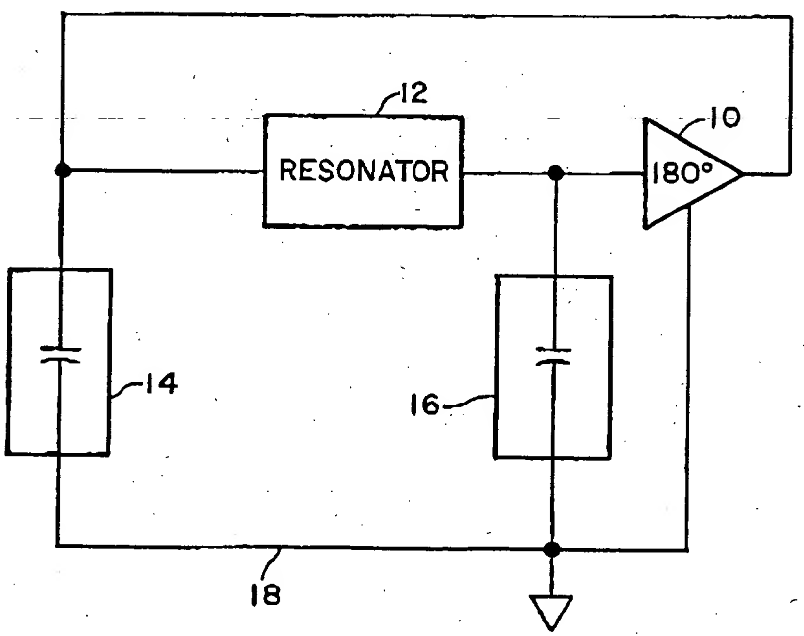

Fig. 2b

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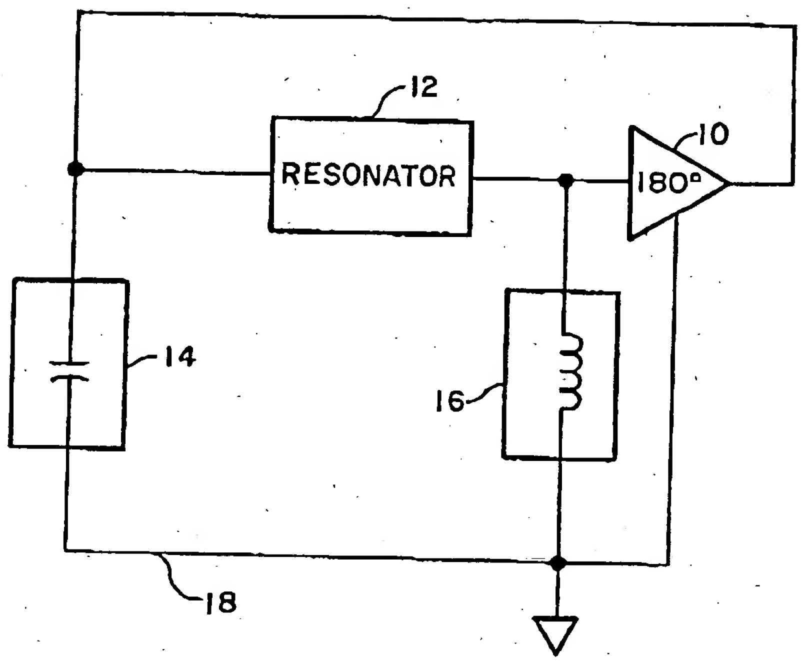

Fig. 2c

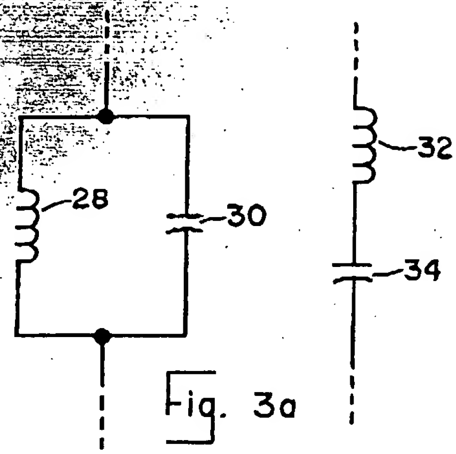

Fig. 3a

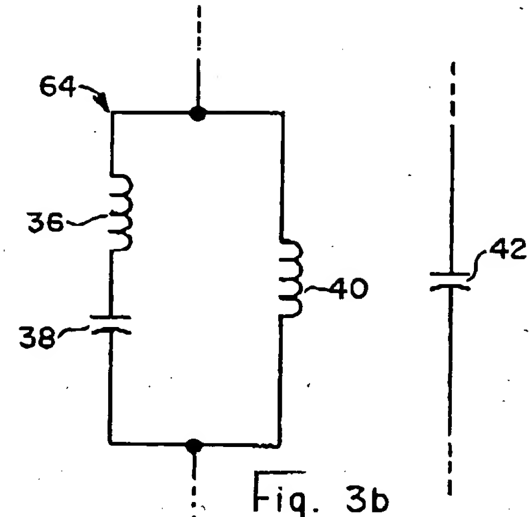

Fig. 3b

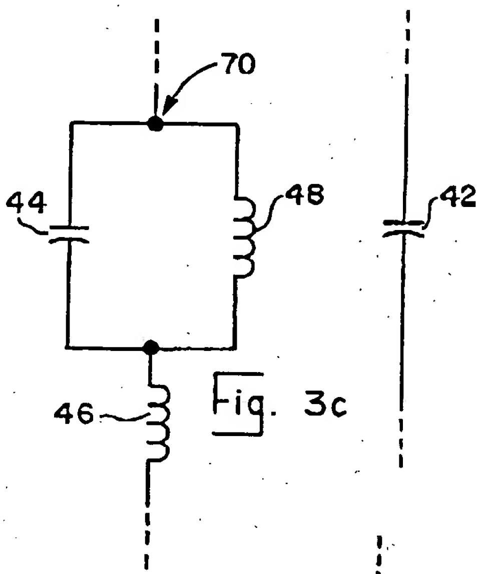

Fig. 3c

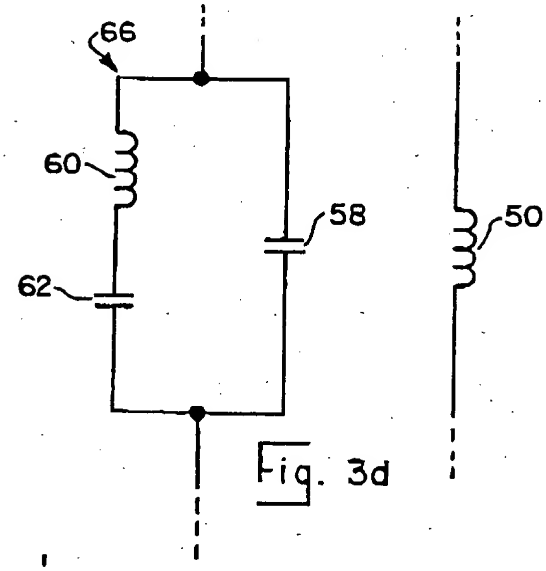

Fig. 3d

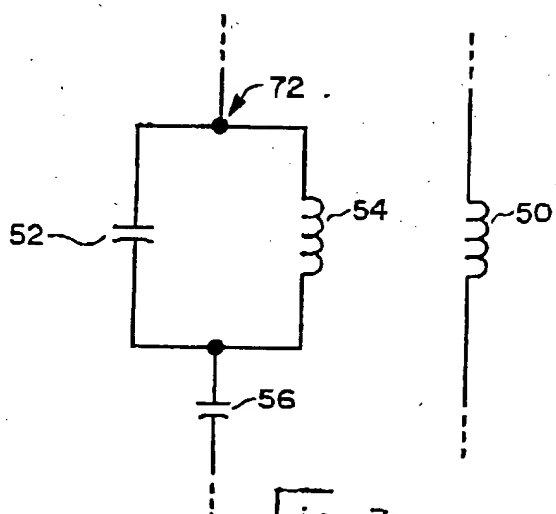

Fig. 3e

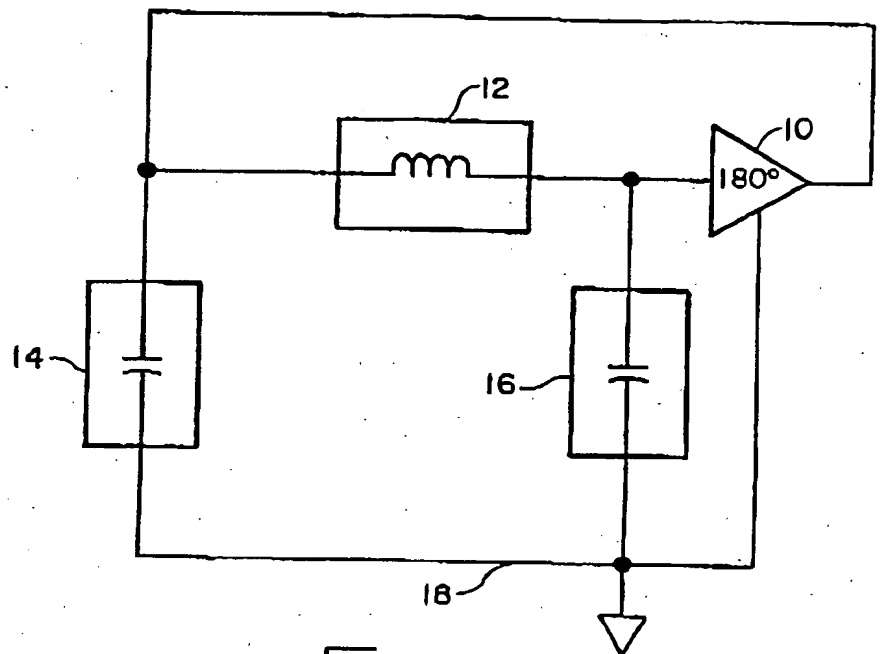

Fig. 4a (PRIOR ART)

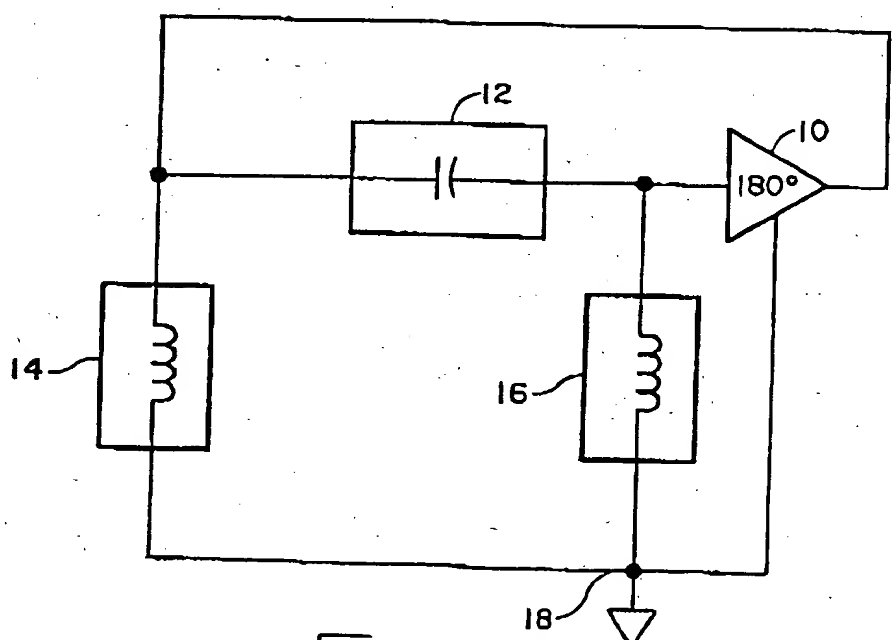

Fig. 4b (PRIOR ART)

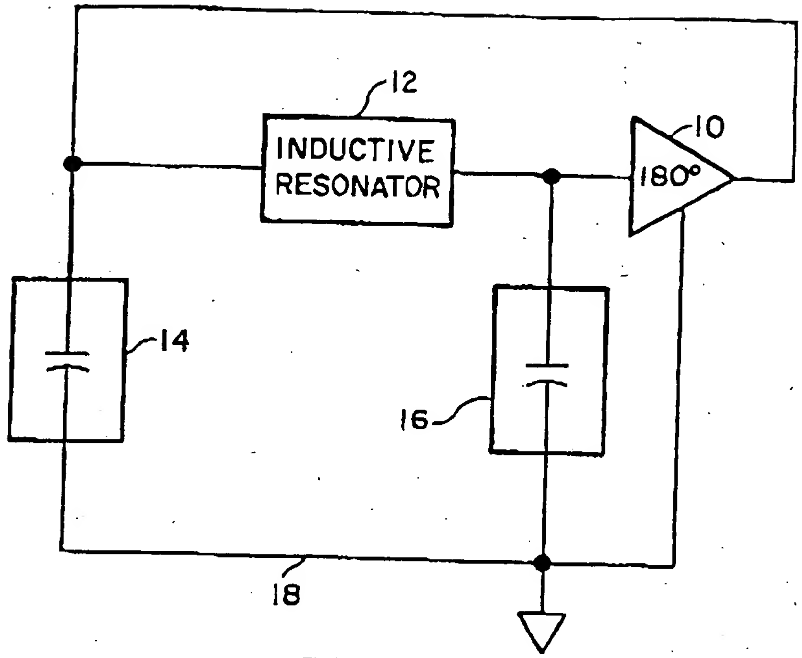

Fig. 5a (PRIOR ART)

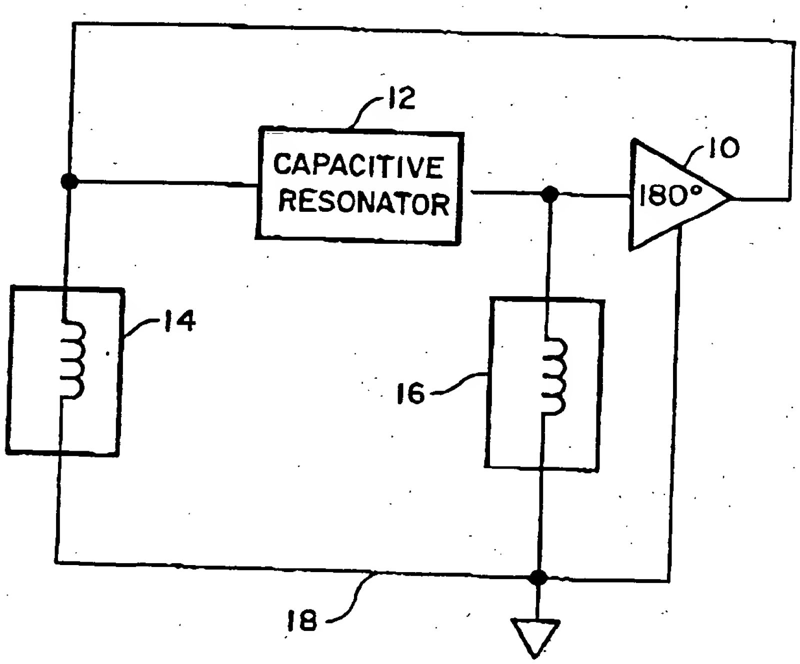

Fig. 5b (PRIOR ART)

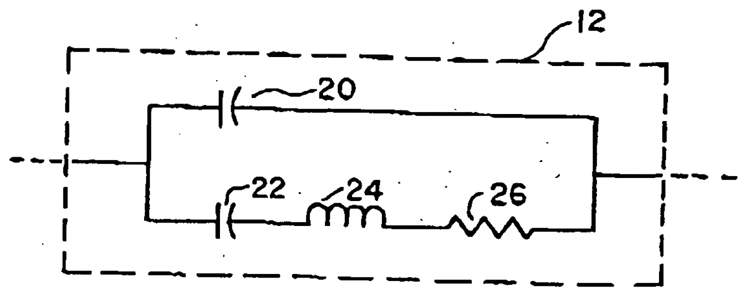

Fig. 6a (PRIOR ART)

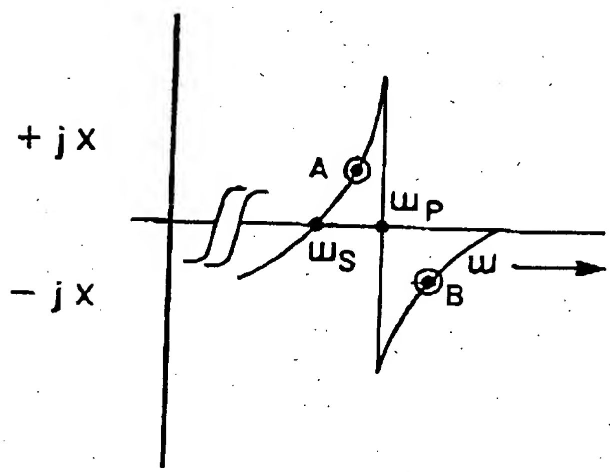

Fig. 6b (PRIOR ART)

SPECIFICATION

Oscillator mode suppression apparatus having bandpass effect

This invention is concerned generally with oscillators, and more particularly with resonator oscillators that generate a signal within a selected band of frequencies having no unwanted or spurious outputs above or below the selected band frequencies.

A typical resonator oscillator will oscillate not only at the frequency for which it was designed, but also at certain harmonics and sub-harmonics of that frequency, plus other spurious frequencies. To separate the desired frequency from the others, various mode suppression techniques have been employed in the past. These techniques include: resonant traps to suppress each unwanted frequency; low pass traps for frequencies below the desired frequency; and post oscillator filters.

Each of these approaches is a limited, incomplete, solution to the problem. The resonant trap approach requires that each of the unwanted frequency modes be identified and a separate filter be included in the circuit to suppress each of those modes. This results in the addition of a large number of additional parts which addition quickly increases the resistive loss in the circuit.

The low pass trap approach, while requiring fewer additional parts than the resonant trap approach, only removes the undesired modes below the desired mode. There is no suppression of the higher frequency modes. A Pierce oscillator of the type described on page 70 and shown in Figs. 7–2 on page 59 of *Crystal Oscillator Design and Temperature Compensation* by Marvin E. Frerking, is illustrative of this type of mode suppression.

Post oscillator filters, while often providing a satisfactory solution to the problem, probably more often than not do not present a satisfactory solution. The downfall of this solution comes when the desired frequency mode is weak and is dominated by one or more stronger unwanted modes. Murphy's law tells us that it is more likely that the mode we are interested in will be the weak mode.

To overcome the shortcomings of each of the above-mentioned techniques, the circuit of the oscillator feedback path should be such that the phase of the feedback signal is 180° only for a narrow band of frequencies which includes the desired frequency. Through the use of such an approach, any number of unwanted oscillation modes both above and below the desired oscillation frequency could be suppressed successfully.

The present invention presents such an approach.

The present invention provides a signal oscillator with mode suppression apparatus for selected band of frequencies, said apparatus comprising: inverting amplifier means having an input terminal and an output terminal; and signal feedback means, said signal feedback means including: crystal resonator means connected in series between the input and output terminals of the inverting amplifier means for producing a relatively stable oscillator output signal; and first and second shunt reactive means, one of said first and second shunt reactive means having one end connected to the input terminal of the inverting amplifier means, the other of said first and second shunt reactive means having one end connected to the output terminal of the inverted amplifier means, and the other ends of each of the first and second shunt reactive means being connected one to the other; at least one of said first and second shunt reactive means having a resonant tank circuit, said resonant tank circuit having a reactance value of the same sign as the reactance value of the other of said first and second shunt reactive means and a different sign than the reactive value of the crystal resonator means for providing a 180° phase shift through the signal feedback means in the selected band of frequencies.

In the apparatus set forth in the last preceding paragraph, it is preferred that one of said first and second shunt reactive means includes a parallel resonant tank and the other of said first and second shunt reactive means includes a series resonant tank.

In the apparatus set forth in the last preceding paragraph, it is preferred that said parallel resonant tank has a resonant frequency, f_1, and said parallel tank has a negative reactance above f_1 and a positive reactance below f_1; and said series resonant tank has a resonant frequency, f_2, and said series tank has a positive reactance above f_2 and a negative reactance below f_2; said resonant frequencies f_1 and f_2 defining said selected band of frequencies.

In the apparatus set forth in the last preceding paragraph, f_1 may be selected to be less than f_2 causing said crystal resonator means to assume a positive reactance value between f_1 and f_2 and the oscillator to operate in the Colpitts or Pierce configuration between frequencies f_1 and f_2. Alternatively f_2 is selected to be less than f_1 causing said crystal resonator means to assume a negative reactance value between f_2 and f_1 and the oscillator to operate in the Hartley configuration between frequencies f_2 and f_1.

In the apparatus set forth in the last preceding paragraph but three, it is preferred that one of said first and second shunt reactive means includes a tank circuit having a series resonant path and a parallel resonant path; the other of said first and second shunt reactive means includes a first non-resonant reactive circuit; and a tank circuit

and a parallel resonant frequency, these frequencies defining the band of frequencies between which oscillation is possible.

In the apparatus set forth in the last preceding paragraph, it is preferred that the tank circuit comprises a series resonant reactive circuit path in parallel with a second non-resonant reactive circuit path.

In the apparatus set forth in the last preceding paragraph, it is preferred that the series resonant reactive circuit path comprises an inductor connected in series with a capacitor.

In the apparatus set forth in the last preceding paragraph, it is preferred that said second non-resonant reactive circuit path comprises an inductor; and said first non-resonant reactive circuit comprises a capacitor.

In the apparatus set forth in the last preceding paragraph, it is preferred that said second non-resonant reactive circuit path comprises a capacitor; and said first non-resonant reactive circuit comprises an inductor.

In the apparatus set forth in the last preceding paragraph but four, it is preferred that the tank circuit comprises a parallel resonant reactive circuit path in series with a second non-resonant reactive circuit path.

In the apparatus set forth in the last preceding paragraph, it is preferred that the parallel resonant reactive circuit path comprises an inductor connected in parallel with a capacitor.

In the apparatus set forth in the last preceding paragraph, it is preferred that said second non-resonant reactive circuit path comprises an inductor; and said first non-resonant reactive circuit comprises a capacitor.

In the apparatus set forth in the last preceding paragraph, it is preferred that said second non-resonant reactive circuit path comprises a capacitor; and said first non-resonant reactive circuit comprises an inductor.

In accordance with the preferred embodiment, the present invention includes an inverting amplifier and a feedback path between the input and output terminals of the amplifier. This feedback path includes a series reactive element in the form of a crystal resonator and a pair of shunt reactive elements one end of each being connected to the two ends of the crystal resonator and the second ends of the shunt elements being connected together to form a common line.

There are two basic embodiments of the present invention. They are a two-arm bandpass mode suppression configuration. In the two-arm configuration one of the shunt reactive elements includes a parallel resonant tank and the second of the shunt reactive elements includes a series resonant tank. Each of these tanks have a resonant frequency at which the sign of the reactance of the tank switches from positive to negative. By the proper choice of the values of the capacitors and inductors in each of the

resonant frequencies can be made to define a band of frequencies substantially between which the feedback path provides a phase shift of 180°.

In the one-arm bandpass mode suppression configuration one of the shunt elements includes a non-resonant reactive circuit, while the other shunt element includes a resonant tank with both a series and a parallel resonant path. In this configuration the series resonant frequency and the parallel resonant frequency of that shunt element define the band of frequency between which oscillation is possible.

Each of these configurations lends itself equally to both the Colpitts or Pierce and the Hartley oscillator configurations. In each of these basic osillator configurations, a feedback path phase shift 180° is only possible when the sign of the series reactance element is different from the sign of both of the shunt reactance elements. To achieve this within the desired band of frequencies, the sign of the effective reactance of the shunt reactive elements must match in that range. This can be achieved again by the proper selection of the values of the capacitors and inductors that used in the shunt reactive element tank circuits.

There now follows a detailed description which is to be read with reference to the accompanying drawings of embodiments according to the present invention and examples of the prior art; it is to be clearly understood that the embodiments of the invention hereinafter described have been selected for description by way of example and not by way of limitation.

In the accompanying drawings:—

Figure 1 is a schematic representation of one embodiment of the circuit of an oscillator according to the present invention oscillating only within a selected range of frequencies;

Figures 2a, 2b and 2c are schematic representations of the circuit of Fig. 1 operating in a Colpitts or Pierce configuration at frequencies below, between, and above, respectively, two preselected frequencies that define the band in which the circuit oscillates;

Figures 3a to 3e are schematic representations of additional shunt arm circuit pair configurations that may be substituted for the pair shown in Fig. 1;

Figures 4a and 4b are schematic representations of basic Colpitts and Hartley oscillators, respectively;

Figures 5a and 5b are schematic representations of oscillators having a series resonator element in the Colpitts and Hartley configurations, respectively;

Figure 6a is a schematic representation of an equivalent circuit of a crystal resonator; and

Figure 6b is a graphical representation of

frequency.

Figs. 4a and 4b show simplified circuit diagrams of two well known oscillator circuits. Each of these circuits includes an inverting amplifier 10, a series reactive element 12, and two shunt reactive elements 14 and 16. The shunt reactive elements 14 and 16 have one end connected to opposite ends of the series reactive element 12. The other end of each of the shunt reactive elements 14 and 16 is connected in common to a return line 18. The junction between the series reactive element 12 and the shunt reactive element 16 is connected to the input terminal of the inverting amplifier 10. Additionally, the output of the inverting amplifier 10 is connected to the junction between the series reactive element 12 and the shunt reactive element 14. The circuit configuration in Fig. 4a includes an inductor as the series reactive element 12, and capacitive elements 14 and 16, making this a Colpitts type oscillator. Fig. 4b shows a complimentary circuit wherein the series reactive element 12 is a capacitor and the shunt reactive elements 14 and 16 are inductors making this a Hartley type oscillator.

Figs. 5a and 5b represent oscillator circuits which are similar to the Colpitts and Hartley type circuits respectively of Figs. 4a and 4b. In each of these circuits, the series reactive element 12 as shown in Figs. 4a and 4b has been replaced with a resonator element such as a crystal resonator. A crystal resonator has the advantage of appearing to have either a capacitive or an inductive reactance characteristic depending on the tuning effect of the shunt reactive elements. The advantage of using a crystal resonator instead of the simple series reactive elements of Figs. 4a and 4b is that it typically has a very high Q or phase-to-frequency slope relationship resulting in a much stabler output frequency.

Fig. 6a shows an equivalent circuit for a crystal resonator having both a series and a parallel resonance path. It is this combination of resonances that permits the crystal resonator to be used as either an inductive or a capacitive reactance in an oscillator circuit. A reactance-versus-frequency curve of the equivalent circuit of a crystal resonator is shown in Fig. 6b. From this Figure we can see that when a crystal resonator is used as the series reactive element 12 in a Colpitts type oscillator (Fig. 5a), it acts as an inductive element operating at a point between series resonance, ω_s and parallel resonance, ω_p, on the positive going portion of the curve. This being a positive reactive portion of the curve indicates that crystal is inductive at this frequency. The exact location of point A between ω_s and ω_p depends on the equivalent capacitance of the remainder of the oscillator circuit. If the crystal resonator is used in place of the series reactive element 12 in the Hartley type circuit be a capacitor and operate at point B on the negative going portion of the reactance curve. In the negative portion of the ractance curve, the crystal resonator has a capacitive reactance.

One embodiment of the present invention is shown in Fig. 1. The oscillator circuit depicted in this Figure is similar to those shown in Figs. 4a and 4b. Here the series reactive element 12 is shown as a resonator, typically a crystal resonator, and the shunt reactive elements 14 and 16 are shown respectively as a parallel reactive tank circuit and a series reactive tank circuit. This approach is a two-arm bandpass mode suppression approach. In this Figure the shunt reactive element 14 consists of an inductor 28 connected in parallel with a capacitor 30 and the shunt reactive element 16 consists of an inductor 32 connected in series with a capacitor 34. A variable capacitor 68 is shown connected in series with a resonator 12 and provides a small degree of fine tuning for the oscillator frequency (point A of Fig. 6b).

As in any oscillator, it is necessary that the feedback circuit provides a 180° phase shift in order to obtain oscillation. This 180° phase shift can only be obtained when the series reactive element 12 has a reactance characteristic that is of a different sign from that of the two shunt reactive elements 14 and 16, i.e., if the series reactive element 12 is inductive having positive reactance, then for the circuit to oscillate, both of the shunt reactive elements 14 and 16 must be capacitive, having negative reactance. To achieve this result in the circuit of Fig. 1, it is necessary to select the element values of the inductors 28 and 32 and of the capacitors 30 and 34 in such a way that this result is achieved in a preselected band of frequencies. Since we are using a crystal resonator as the series reactive element 12, the band which is selected must contain one of the frequencies of oscillation of that resonator.

Thus, if we choose to operate the circuit in the Colpitts or Pierce configuration, the resonator 12 will have to appear to be inductive when both of the shunt reactive elements 14 and 16 appear to be capacitive. To obtain oscillation of the circuit of Fig. 1 only within a selected band of frequencies it is necessary to select the component values of the individual elements of the shunt reactive elements 14 and 16 such that their resonance frequencies are the upper and lower oscillation band frequencies. Additionally, it is necessary for both of the shunt reactive elements 14 and 16 to have a negative, or capacitive, reactance between those frequencies. A parallel tank of the type shown as the shunt reactive element 14 in Fig. 1 has an inductive reactance below its resonant frequency, f_1, and a capacitive reactance above f_1. Similarly, the series tank of

element 16 has a capacitive reactance below its resonant frequency, f_2, and inductive reactance above f_2. Thus, f_1 must be less than f_2 so that the shunt reactive elements 14 and 16 both have a negative or capacitive, reactance between f_1 and f_2 to achieve the desired bandpass effect. In this case the oscillator will have the necessary 180° phase shift in the feedback circuit only between the frequencies f_1 and f_2. If we had chosen to operate the oscillator in the Hartley configuration, we would have selected the values of the inductors 28 and 32, and of the capacitors 30 and 34 such that the shunt reactive elements 14 and 16 both appear to be inductive within the desired band. To achieve that result, f_1 would have to be greater than f_2.

In Figs. 2a, 2b and 2c there is shown the circuit of Fig. 1 operating in the Colpitts configuration. The circuit in Fig. 2a represents the effective reactance of the shunt reactive elements 14 and 16 below the lower band limit frequency, f_1, wherein the shunt reactive element 14 has an inductive reactance and the shunt reactive element 16 has a capacitance reactance. Therefore, no oscillation occurs since in this configuration there would not be a 180° phase shift in the feedback circuit. Fig. 2b similarly shows the shunt reactive elements 14 and 16 between the selected band frequencies f_1 and f_2. Here both the shunt reactive elements 14 and 16 have a capacitive reactance and therefore the necessary 180° phase shift required for oscillation is present in the feedback circuit. Finally, in Fig. 2c the shunt reactive elements 14 and 16 are shown as to their effective values above the upper band frequency, f_2. Here again the shunt elements have dissimilar reactances and therefore there would be no oscillation.

Figs. 3a to 3e represent a number of various shunt reactive element combinations that may be used for the shunt reactive circuits 14 and 16. Fig. 3a shows the circuits of the shunt elements that were discussed in relation to Fig. 1 and we have seen that this arrangement lends itself either to the Hartley or to the Colpitts configuration. It should be noted here that the shunt elements of Fig. 3a may be interchanged with the series tank being used for the shunt reactive element 14 and the parallel tank for the shunt reactive element 16 without loss of the desired operating characteristics.

The shunt reactive element circuit pairs shown in Figs. 3b to 3e are of the one arm bandpass mode suppression type. These are designated as such since the entire bandpass effect is created in only one of the shunt legs of the oscillator. Those shown in Figs. 3b and 3c are for a Colpitts type configuration and those shown in Figs. 3d and 3e are for a Hartley configuration. Additional similarity between Figs. 3b and 3d exists wherein the bandpass tank has both a series and a parallel resonance. The similarity between Figs. 3c and 3e exists in that there is a parallel tank in series with either a capacitor or an inductor.

If the shunt circuit pair of Fig. 3b is used in the circuit of Fig. 1 for the shunt reactive elements 14 and 16 respectively, or in the reverse order, a series parallel tank of the shunt arm labelled 64 will have an inductive characteristic at the high and low frequencies and a capacitive characteristic in the desired band region. As $\omega \rightarrow \infty$ the reactance of capacitor 38 approaches a short circuit so that the shunt leg labelled 64 is effectively reduced to an inductor 36 in parallel with an inductor 40 and therefore has an inductive characteristic. As $\omega \rightarrow 0$, the reactance of the capacitor 38 approaches an open circuit so that the shunt leg 64 effectively reduces to the inductor 40 alone. To understand how the circuit has a capacitive reactance at mid band, we will first consider only the series tank of the inductor 36 and the capacitor 38. The series tank at frequencies below the series resonance, ω_s, has a capacitive reactance. Above this resonance frequency it has an inductive reactance. At its resonance frequency, ω_s, it has a zero impedance or is effectively a short circuit. Very close to and slightly below ω_s, this series tank portion has a capacitive reactance that is close to zero, i.e., it has a large capacitive component. In other words, the series tank looks like the capacitor 38 at low frequencies and its capacitive reactance approaches zero as $\omega \rightarrow \omega_s$. If we now add the effect of the inductor 40 in parallel with the series tank we note that as long as the equivalent capacitive reactance of the series tank is very small this capacitor reactance will shunt out the inductive reactance of the inductor 40 and the total shunt arm 64 will have a capacitive reactance over all and appear to be a capacitor.

The Hartley oscillator pair of shunt elements shown in Fig. 3d operates very similarly to the Colpitts shunt arm circuits shown in Fig. 3b. In the series parallel tank 66 of Fig. 3d, at low and high frequencies it has a capacitive reactance and within the desired band it has an inductive reactance thus providing the bandpass effect that we saw with the shunt arm 64 in Fig. 3b. The series parallel tank 66 operates very similarly to the series parallel tank 64 of Fig. 3b.

Bandpass shunt arm circuits 70 and 72 of Fig. 3c and 3e, respectively, operate in the same way as the shunt arm circuits 64 and 66 of Figs. 3b and 3d, respectively. Through the proper choice of inductor and capacitor values for the shunt leg 70 of Fig. 3c, it can easily be seen that this circuit at low and high frequencies would have an inductive reactance and in a mid band region could be made to have a capacitive reactance. At low

would be very small approaching zero and thus effectively shunting the capacitor 44 leaving the inductor 46 to provide the shunt arm. At high frequencies the reactance of the capacitor 44 approaches zero and effectively shunts the inductor 48. Thus, the shunt arm 70 appears as simply the inductor 46. At mid band, just above the resonance frequency of the capacitor 44 and the inductor 48, the parallel tank would have a high negative reactance while the inductor 46 had a moderate positive reactance and again through proper selection of the circuit elements the sum of the reactances could be made to remain negative within the desired band and thus allow oscillation within that band in the Colpitts configuration.

The Hartley configuration shunt arm 72 shown in Fig. 3e operates in a similar manner to the Colpitts configuration shunt arm 70 of Fig. 3c with just the reverse effect, i.e., at high and low frequencies the shunt arm 72 has a capacitive reactance and in the mid band region has the desired inductive reactance through the proper choice of the element values of the capacitors 52 and 56 and the inductor 54.

CLAIMS

1. A signal oscillator with mode suppression apparatus for limiting the frequencies of oscillation to a selected band of frequencies, said apparatus comprising:

inverting amplifier means having an input terminal and an output terminal; and

signal feedback means, said signal feedback means including:

crystal resonator means connected in series between the input and output terminals of the inverting amplifier means for producing a relatively stable oscillator output signal; and

first and second shunt reactive means, one of said first and second shunt reactive means having one end connected to the input terminal of the inverting amplifier means, the other of said first and second shunt reactive means having one end connected to the output terminal of the inverting amplifier means, and the other ends of each of the first and second shunt reactive means being connected one to the other;

at least one of said first and second shunt reactive means having a resonant tank circuit, said resonant tank circuit having a reactance value of the same sign as the reactance value of the other of said first and second shunt reactive means and a different sign than the reactance value of the crystal resonator means for providing 180° phase shift through the signal feedback means in the selected band of frequencies.

2. A signal oscillator with mode suppression apparatus according to claim 1 wherein one of said first and second shunt reactive means includes a parallel resonant tank; and the other of said first and second shunt reactive means includes a series resonant tank.

3. A signal oscillator with mode suppression apparatus according to claim 2 wherein:

said parallel resonant tank has a resonant frequency, f_1, and said parallel tank has a negative reactance above f_1 and a positive reactance below f_1; and

said series resonant tank has a resonant frequency, f_2, and said series tank has a positive reactance above f_2 and a negative reactance below f_2;

said resonant frequencies f_1 and f_2 defining said selected band of frequencies.

4. A signal oscillator with mode suppression apparatus according to claim 3 wherein f_1 is selected to be less than f_2 causing said crystal resonator means to assume a positive reactance value between f_1 and f_2 and the oscillator to operate in the Colpitts or Pierce configuration between frequencies f_1 and f_2.

5. A signal oscillator with mode suppression apparatus according to claim 3 wherein f_2 is selected to be less than f_1 causing said crystal resonator means to assume a negative reactance value between f_2 and f_1 and the oscillator to operate in the Hartley configuration between frequencies f_2 and f_1.

6. A signal oscillator with mode suppression apparatus according to claim 1 wherein:

one of said first and second shunt reactive means includes a tank circuit having a series resonant path and a parallel resonant path;

the other of said first and second shunt reactive means includes a first non-resonant reactive circuit; and

a tank circuit configured as above defined has a series resonant frequency and a parallel resonant frequency, these frequencies defining the band of frequencies between which oscillation is possible.

7. A signal oscillator with mode suppression apparatus according to claim 6 wherein the tank circuit comprises a series resonant reactive circuit path in parallel with a second non-resonant reactive circuit path.

8. A signal oscillator with mode suppression apparatus according to claim 7 wherein the series resonant reactive circuit path comprises an inductor connected in series with a capacitor.

9. A signal oscillator with mode suppression apparatus according to claim 8 wherein:

said second non-resonant reactive circuit path comprises an inductor; and

said first non-resonant reactive circuit comprises a capacitor.

10. A signal oscillator with mode suppression apparatus according to claim 9 wherein:

said second non-resonant reactive circuit path comprises a capacitor; and

said first non-resonant reactive circuit comprises an inductor.

the tank circuit comprises a parallel resonant reactive circuit path in series with a second non-resonant reactive circuit path.

12. A signal oscillator with mode suppression apparatus according to claim 11 wherein the parallel resonant reactive circuit path comprises an inductor connected in parallel with a capacitor.

13. A signal oscillator with mode suppression apparatus according to claim 12 wherein:

said second non-resonant reactive circuit path comprises an inductor; and

said first non-resonant reactive circuit comprises a capacitor.

14. A signal oscillator with mode suppression apparatus according to claim 13 wherein:

said second non-resonant reactive circuit path comprises a capacitor; and

said first non-resonant reactive circuit comprises an inductor.

15. A signal oscillator with mode suppression apparatus substantially as hereinbefore described with reference to any of Figs. 1, 2a to 2c and 3a to 3e of the accompanying drawings.

CLAIMS (27 June 1980)

1. A signal oscillator with mode suppression apparatus for limiting the frequencies of oscillation to a selected band of frequencies, said apparatus comprising:

inverting amplifier means having input means and output means; and

signal feedback means, said signal feedback means including:

crystal resonator means connected in series between the input and output means of the inverting amplifier means for producing a relatively stable oscillator output signal; and

first and second shunt reactive means, one of said first and second shunt reactive means having one end connected to the input means of the inverting amplifier means, the other of said first and second shunt reactive means having one end connected to the output means of the inverting amplifier means, and the other ends of each of the first and second shunt reactive means being connected one to the other;

said first and second shunt reactive means having a series resonant tank circuit and a parallel resonant tank circuit with the resonant frequencies of the series and parallel circuits being selected so that one of said first and second shunt reactive means has a reactance value of the same sign as the reactance value of the other of said first and second shunt reactive means and a different sign than the reactance value of the crystal resonator means in the selected band of frequencies for providing 180° phase shift through the signal feedback means in that selected band of frequencies.

2. A signal oscillator with mode suppression apparatus according to claim 1 wherein one of said first and second shunt reactive means includes the parallel resonant tank circuit and the other of said first and second shunt reactive means includes the series resonant tank circuit.

3. A signal oscillator with mode suppression apparatus according to claim 2 wherein:

said parallel resonant tank circuit has a resonant frequency, f_1, and said parallel resonant tank circuit has a negative reactance above f_1 and a positive reactance below f_1; and

said series resonant tank circuit has a resonant frequency, f_2, and said series resonant tank circuit has a positive reactance above f_2 and a negative reactance below f_2;

said resonant frequencies f_1 and f_2 defining said selected band of frequencies.

4. A signal oscillator with mode suppression apparatus according to claim 3 wherein f_1 is selected to be less than f_2 causing said crystal resonator means to assume a positive reactance value between f_1 and f_2 and the oscillator to operate in the Colpitts or Pierce configuration between frequencies f_1 and f_2.

5. A signal oscillator with mode suppression apparatus according to claim 3 wherein f_2 is selected to be less than f_1 causing said crystal resonator means to assume a negative reactance value between f_2 and f_1 and the oscillator to operate in the Hartley configuration between frequencies f_2 and f_1.

6. A signal oscillator with mode suppression apparatus according to claim 1 wherein:

one of said first and second shunt reactive means includes a tank circuit being a combination of the series resonant tank circuit and the parallel resonant tank circuit;

the other of said first and second shunt reactive means includes a first non-resonant reactive circuit; and

the tank circuit configured as above defined having a series resonant frequency and a parallel resonant frequency, these frequencies defining the band of frequencies between which oscillation is made possible.

7. A signal oscillator with mode suppression apparatus according to claim 6 wherein the tank circuit comprises a series resonant reactive circuit path in parallel with a

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